

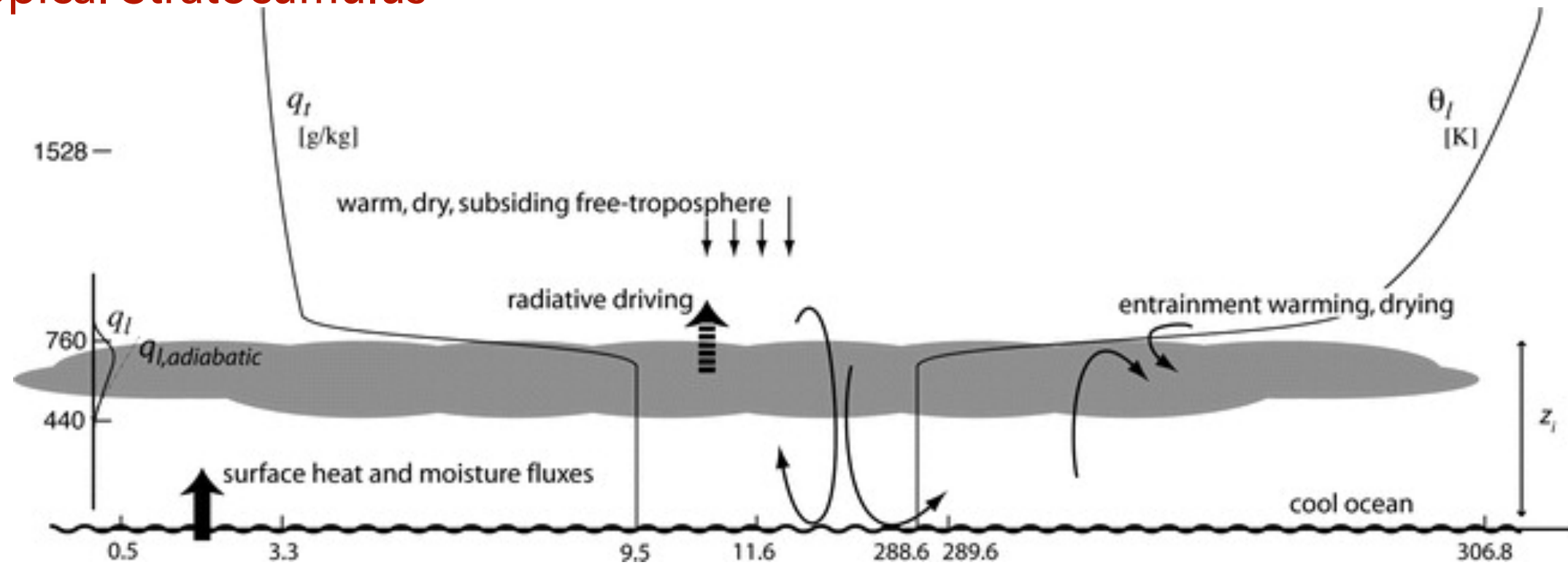
# Cloud-topped boundary layers in climate ...and climate models

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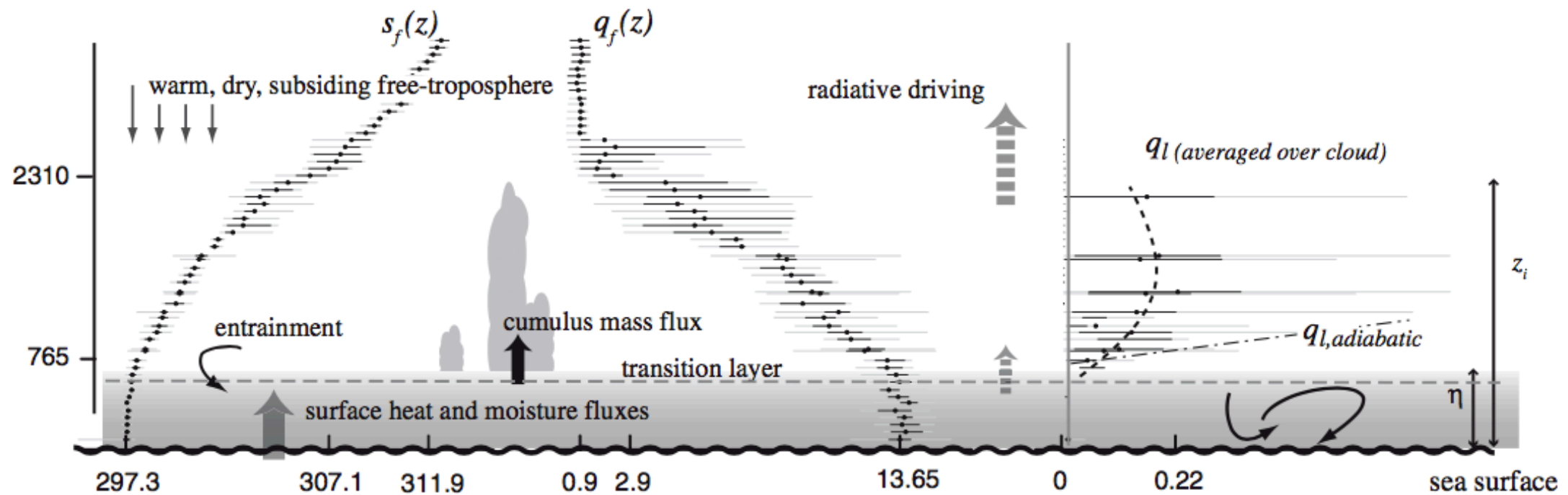
# Marine boundary layer archetypes

## Subtropical Stratocumulus



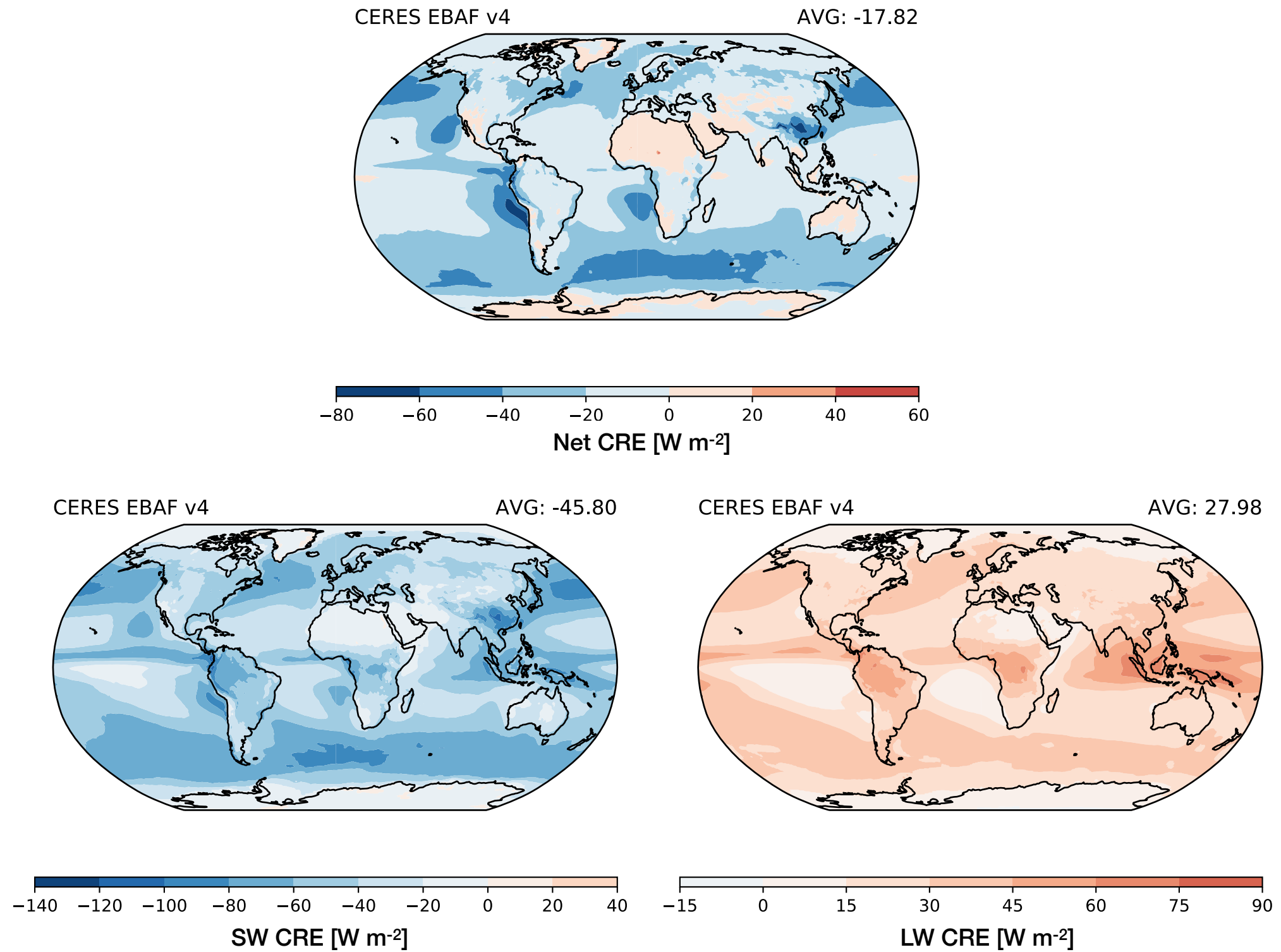
## Trade-wind Cumulus

[Stevens et al. 2007](#)



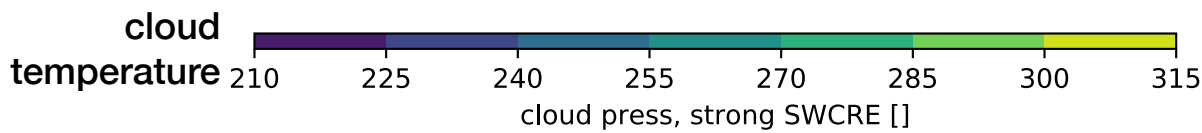
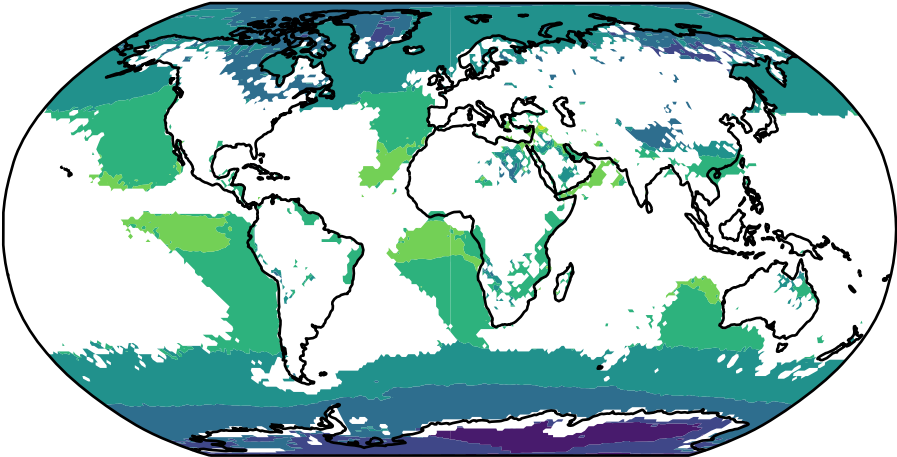
[Stevens et al. 2006](#)

# Observed top-of-atmosphere cloud radiative effects

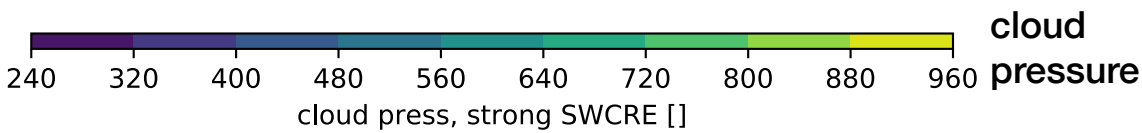
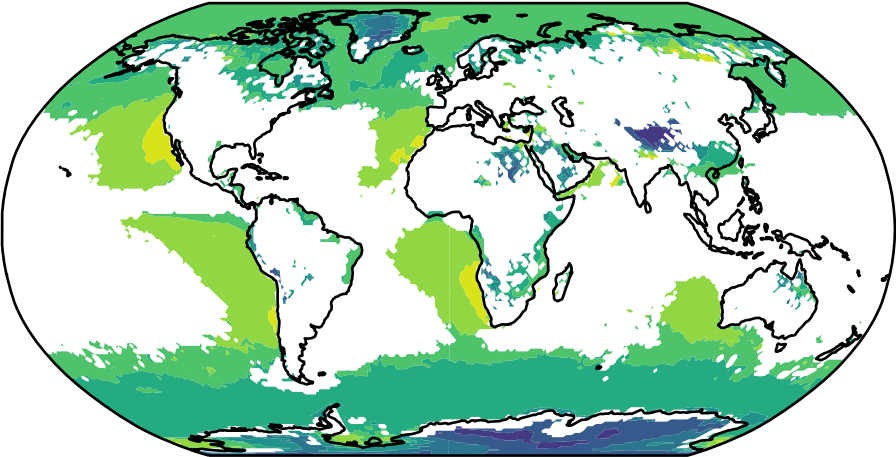


# months when $|SWCRE| > 5 \times |LWCRE|$

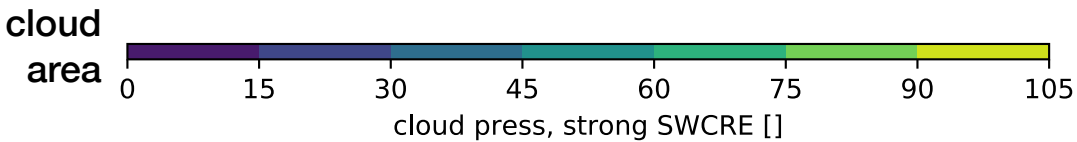
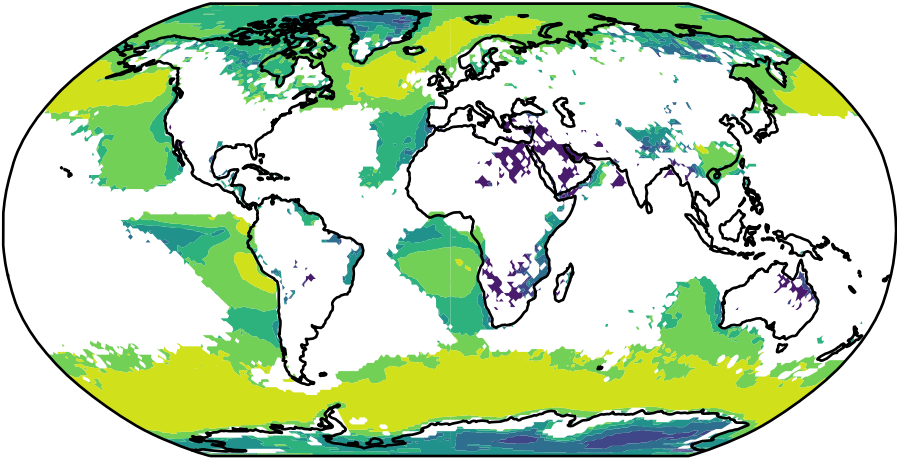
CERES EBAF v4      AVG: 272.31



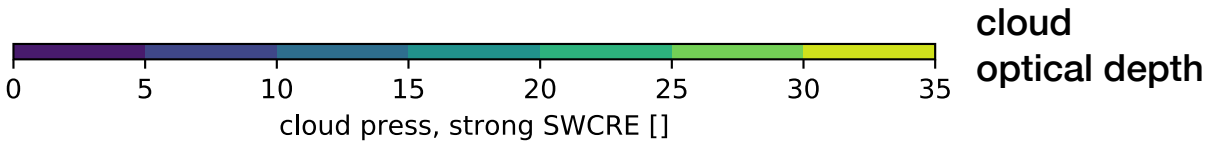
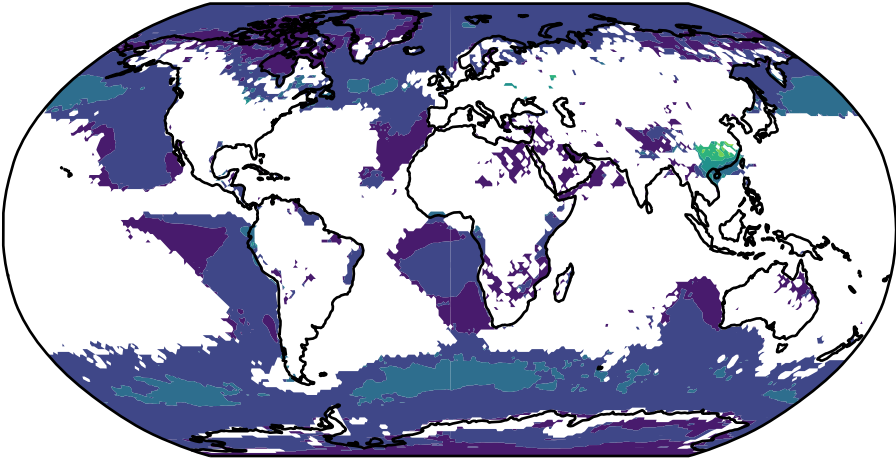
CERES EBAF v4      AVG: 753.36



CERES EBAF v4      AVG: 67.26



CERES EBAF v4      AVG: 6.10

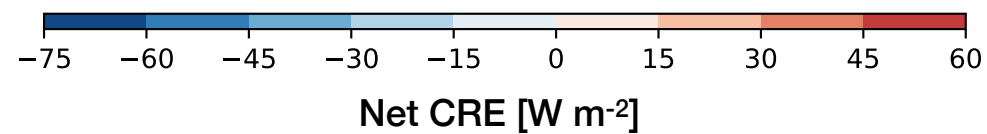
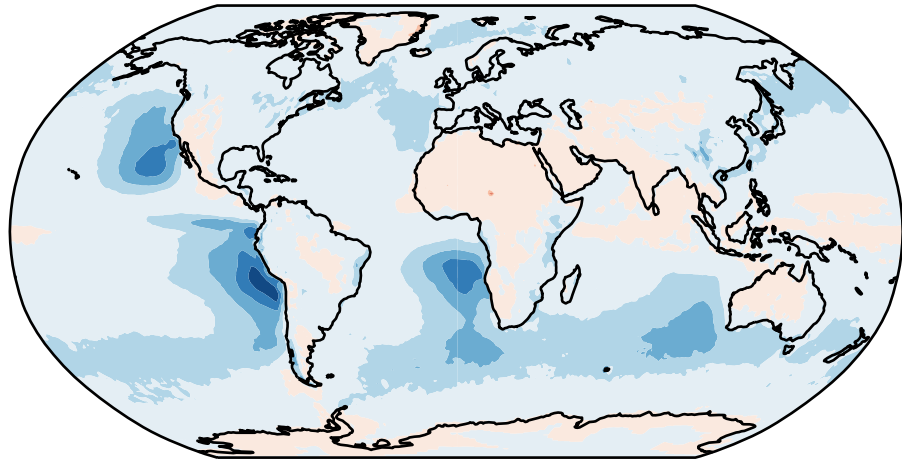




# Observed top-of-atmosphere cloud radiative effects, impact of BL clouds

CERES EBAF v4

AVG: -9.22

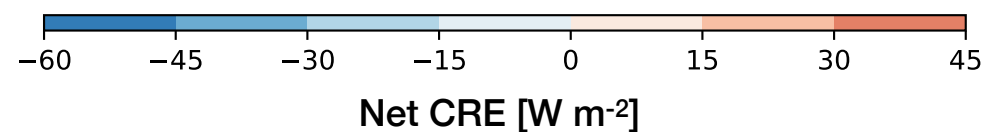
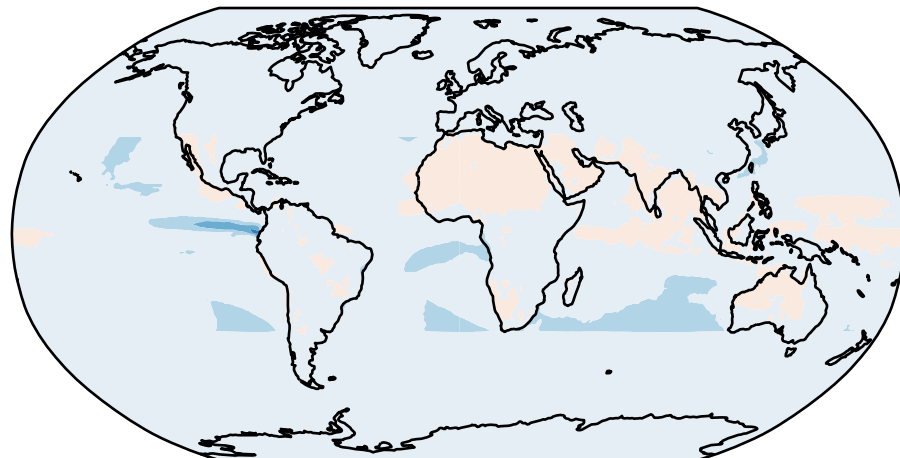


Clouds under large-scale subsidence

tropical trade-wind clouds

CERES EBAF v4

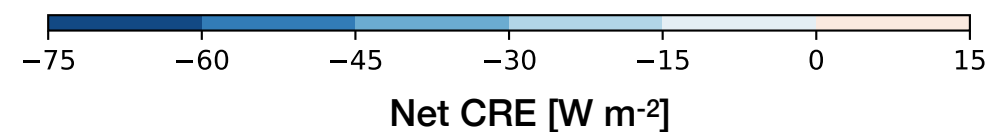
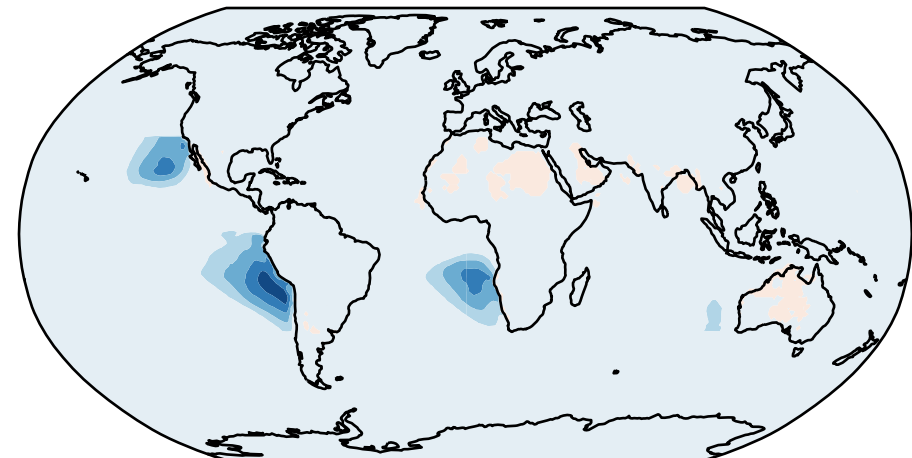
AVG: -2.89



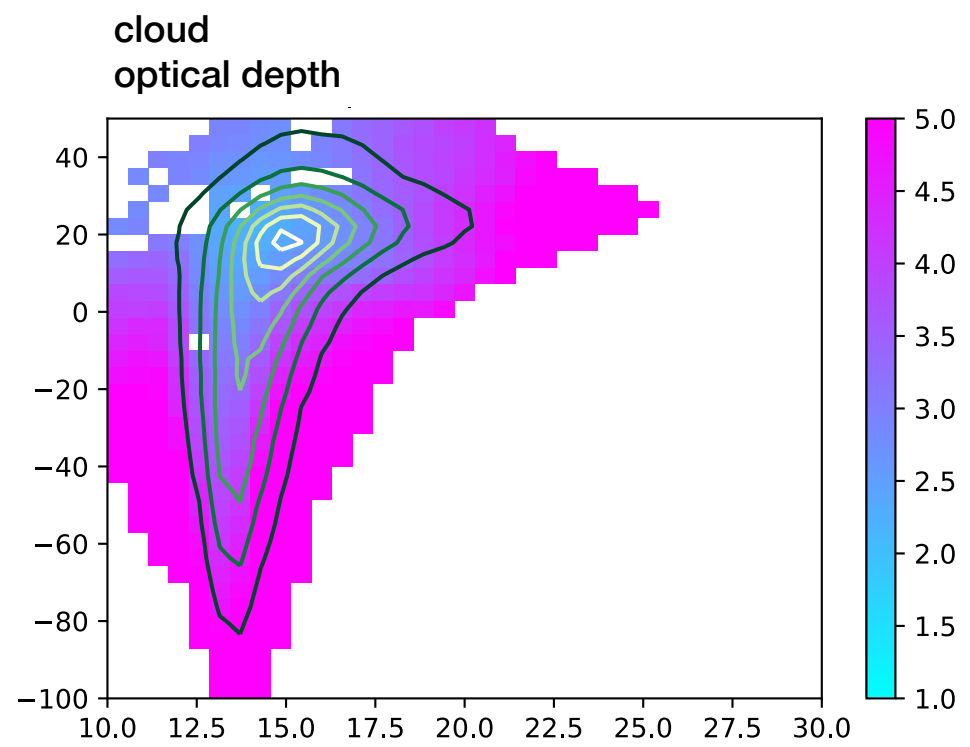
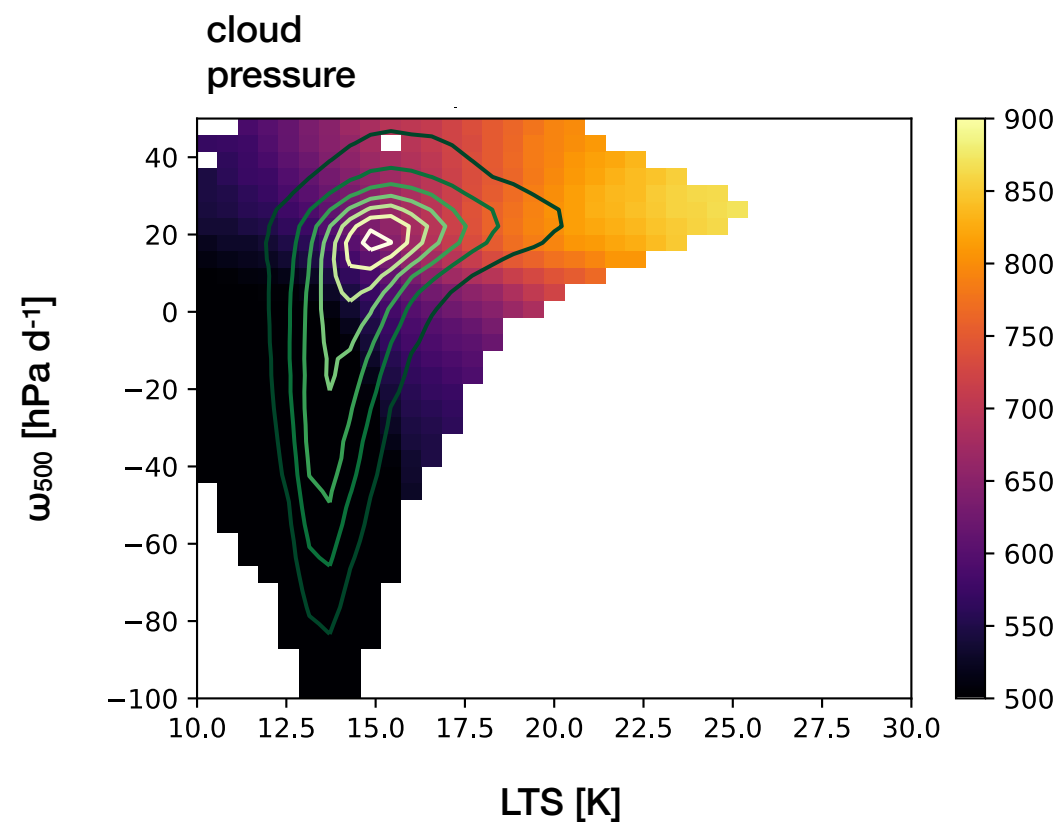
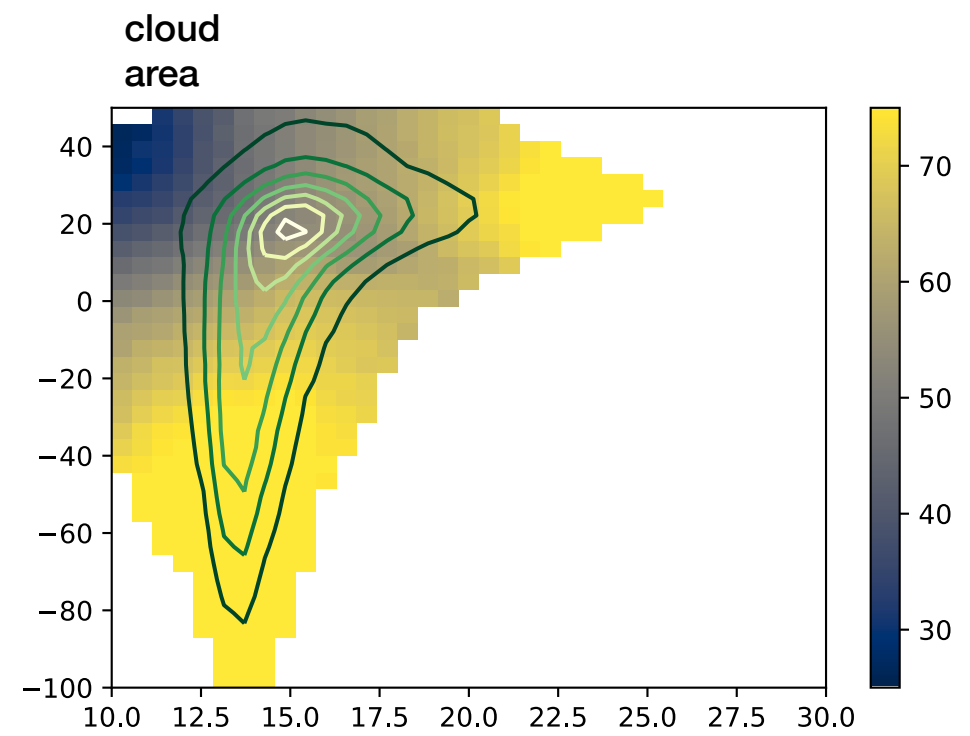
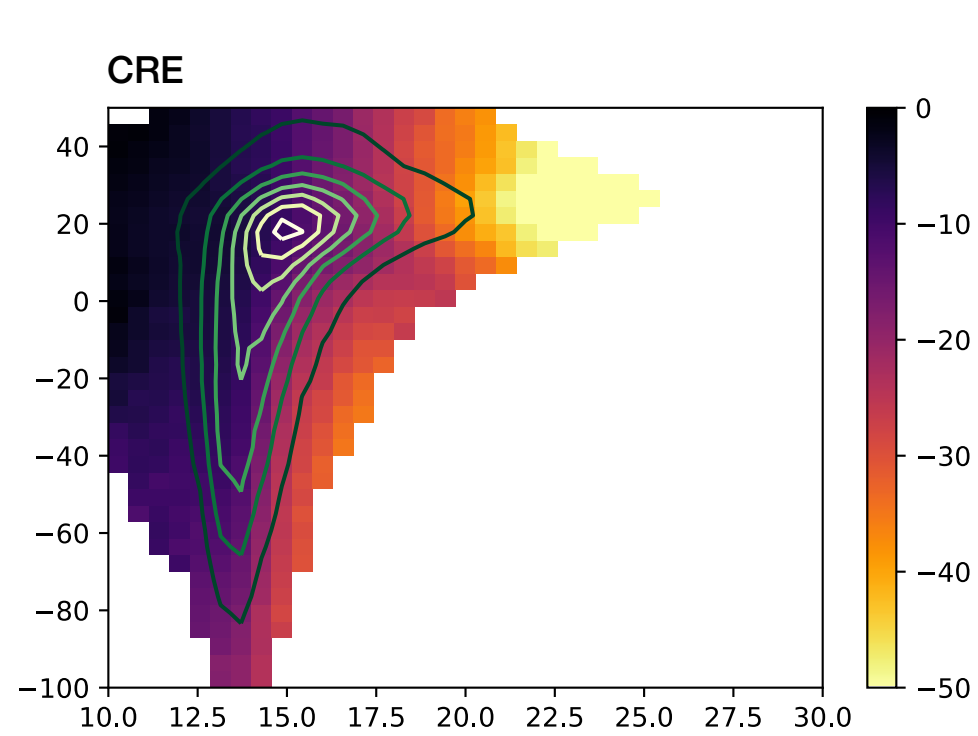
tropical stratocumulus

CERES EBAF v4

AVG: -1.65





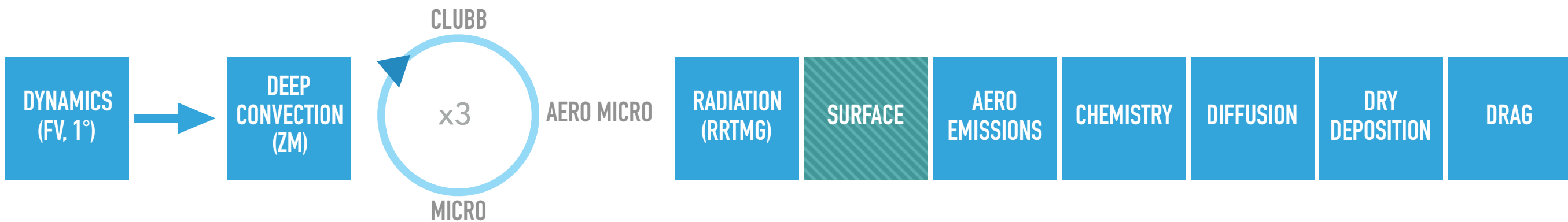




## **Boundary layer clouds in CESM2**



# CESM2 – CAM6



## Model Physics:

Parameterized deep convection (Zhang-McFarlane)

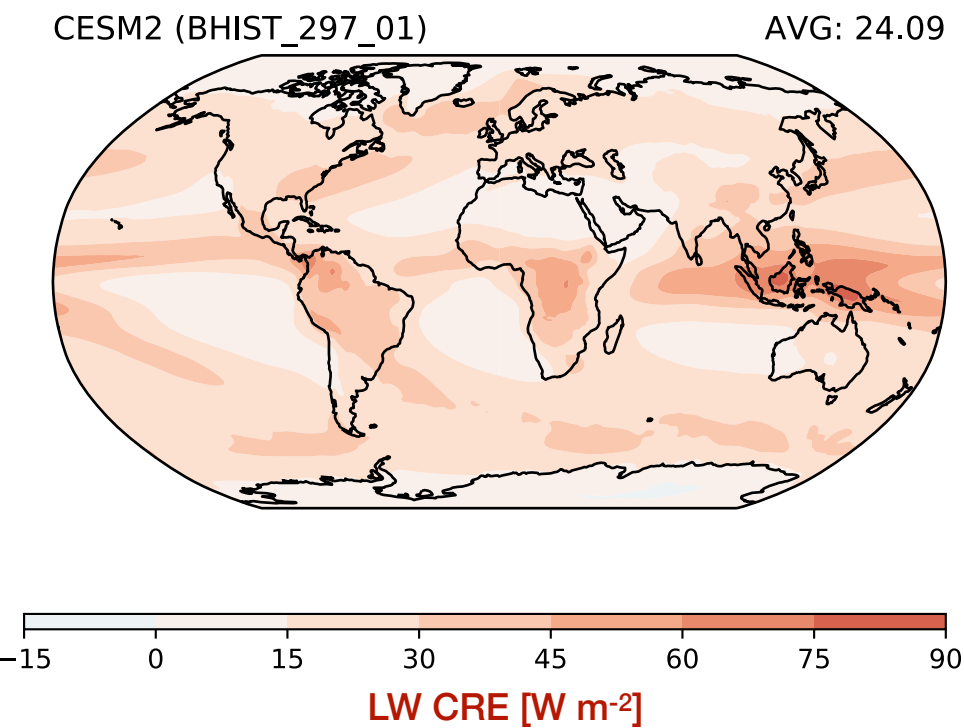
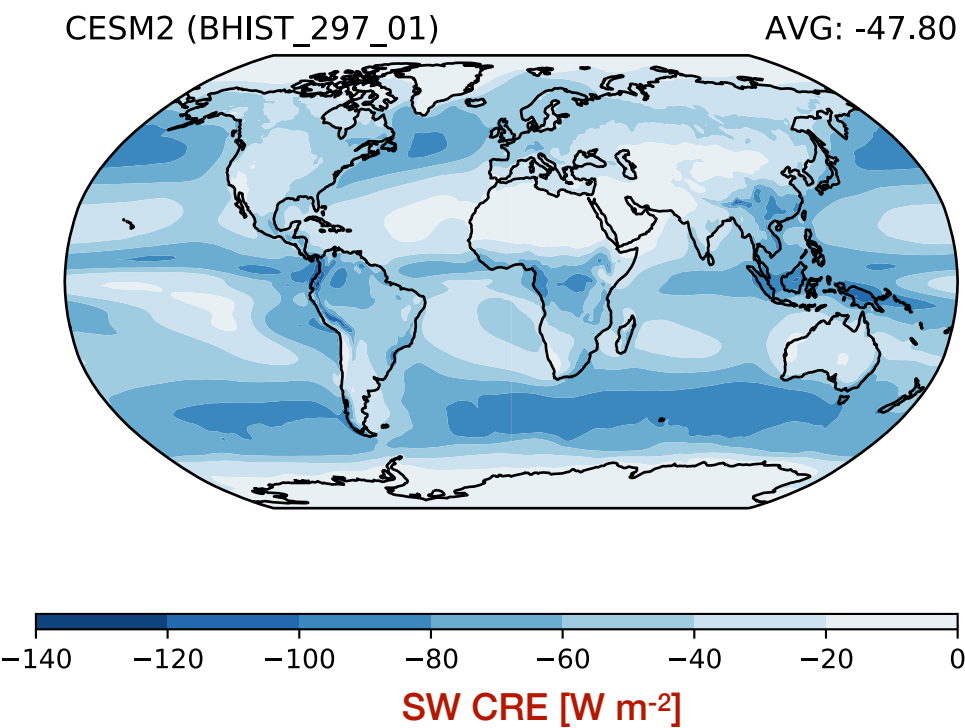
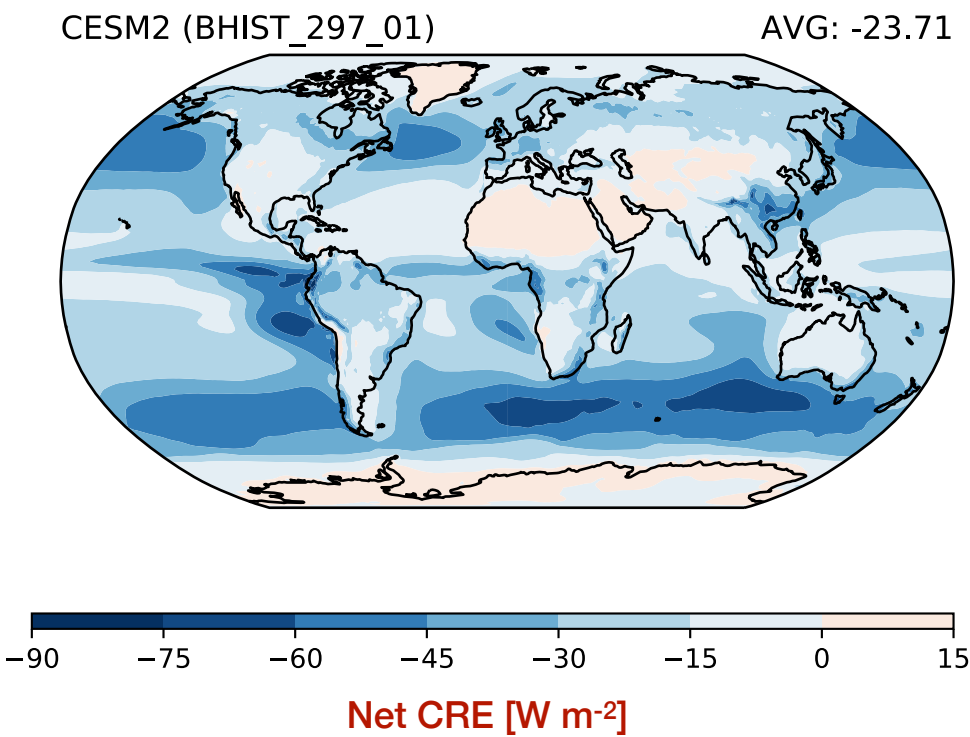
Unified shallow convection – turbulence – cloud macrophysics (CLUBB)

2-moment microphysics (Morrison-Gettelman v2)

4-mode aerosol model with 18 predicted aerosol tracers (MAM4, Liu et al.)



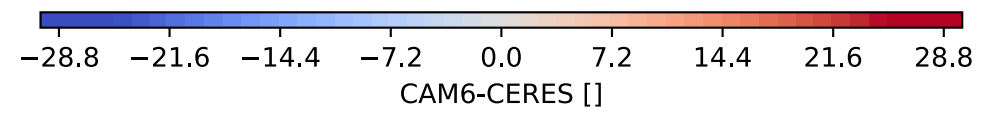
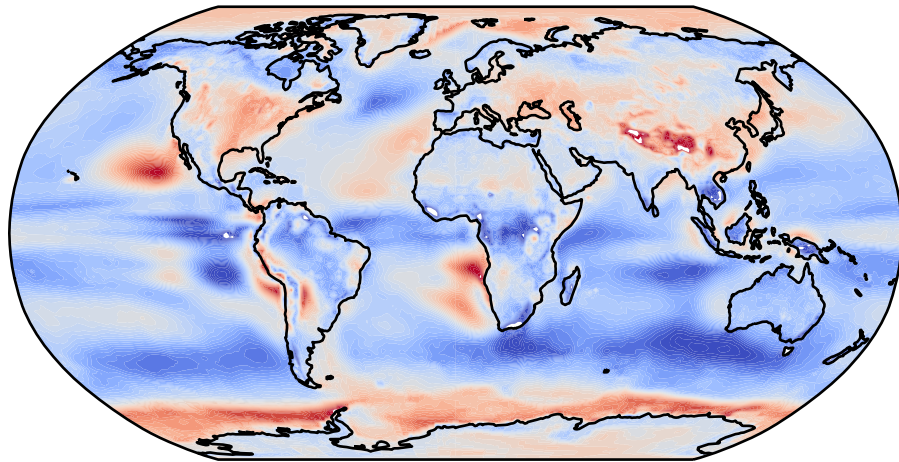
# Simulated top-of-atmosphere cloud radiative effects



## net CRE

CAM6-CERES

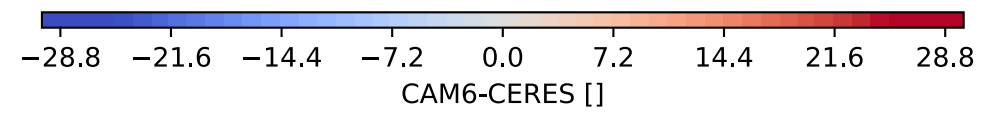
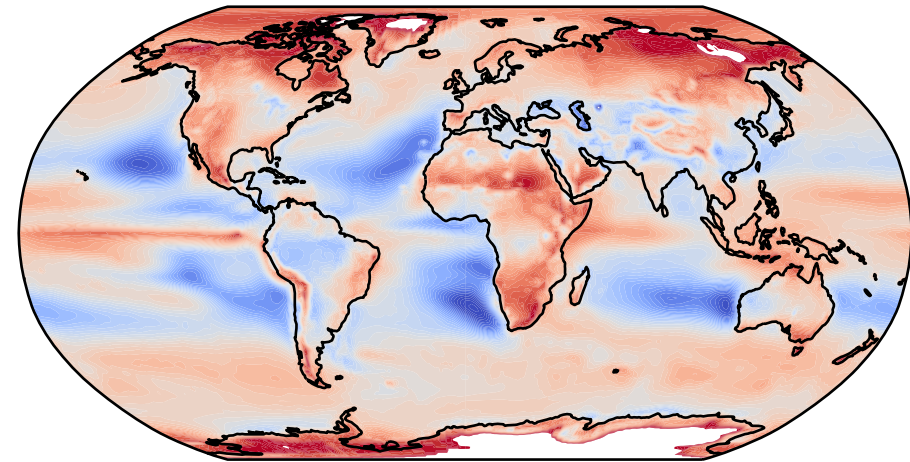
AVG: -5.17



## Cloud Fraction

CAM6-CERES

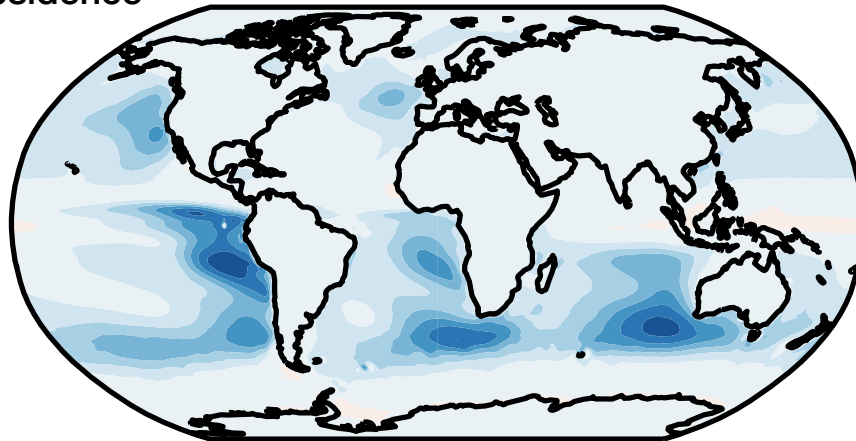
AVG: 2.80





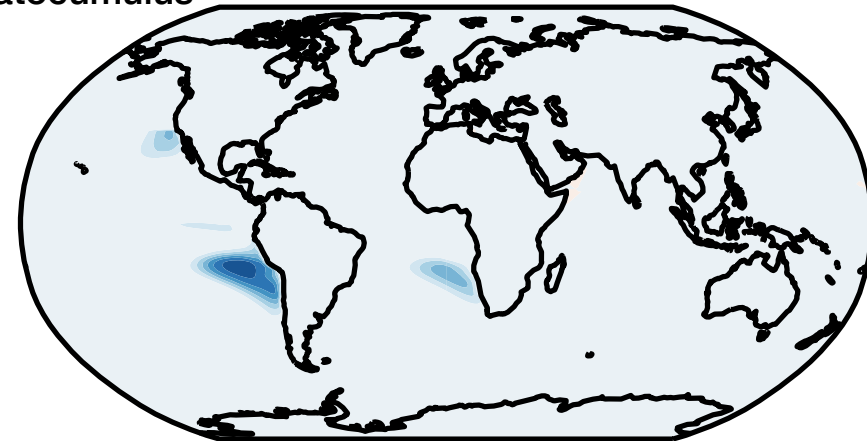
Subsidence

AVG: -10.63



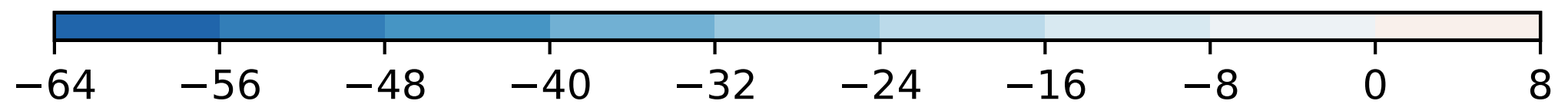
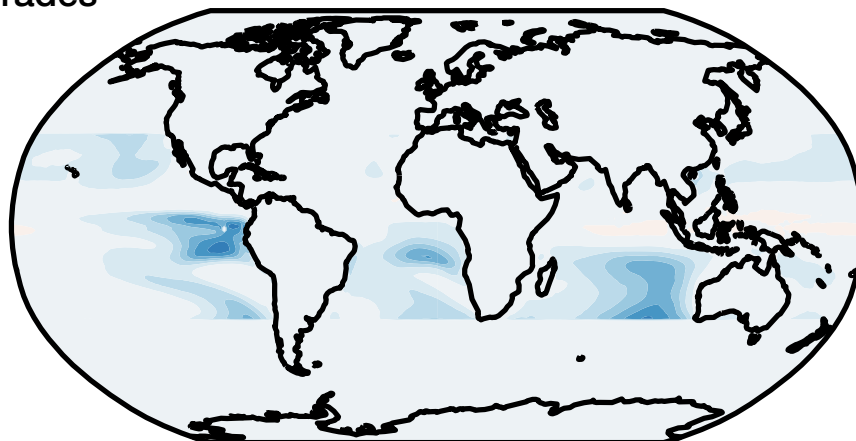
Stratocumulus

AVG: -0.88

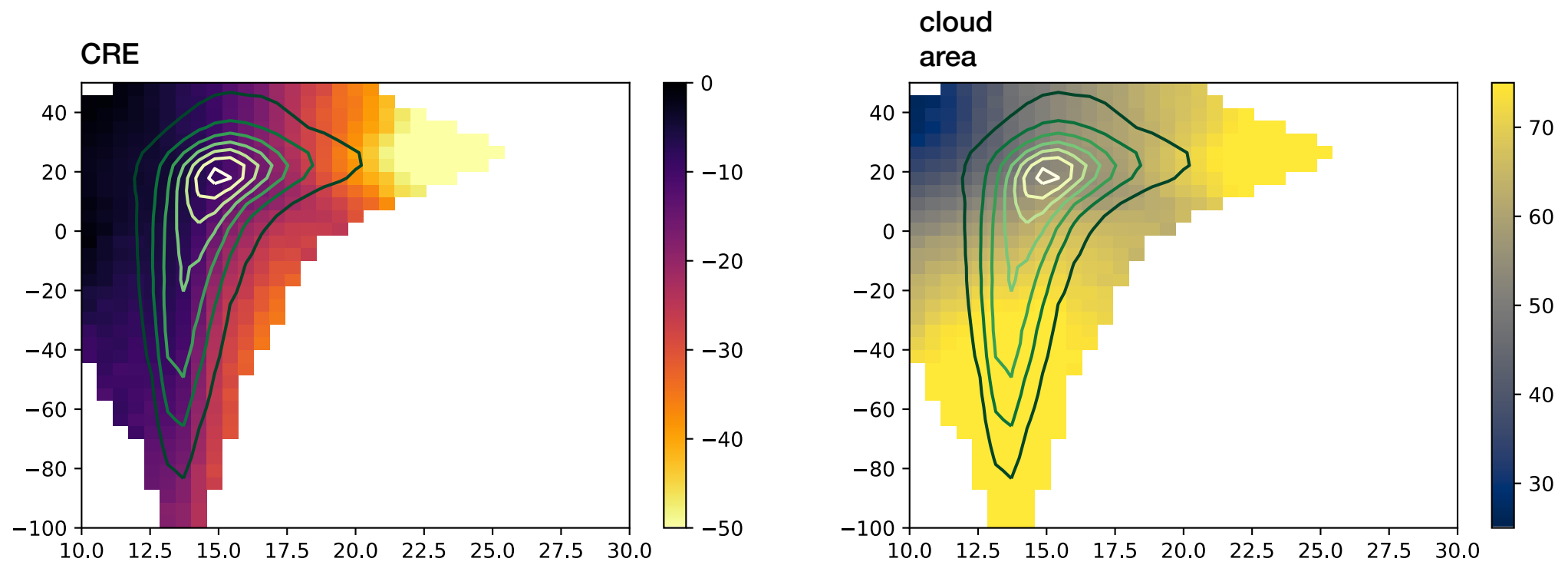


Trades

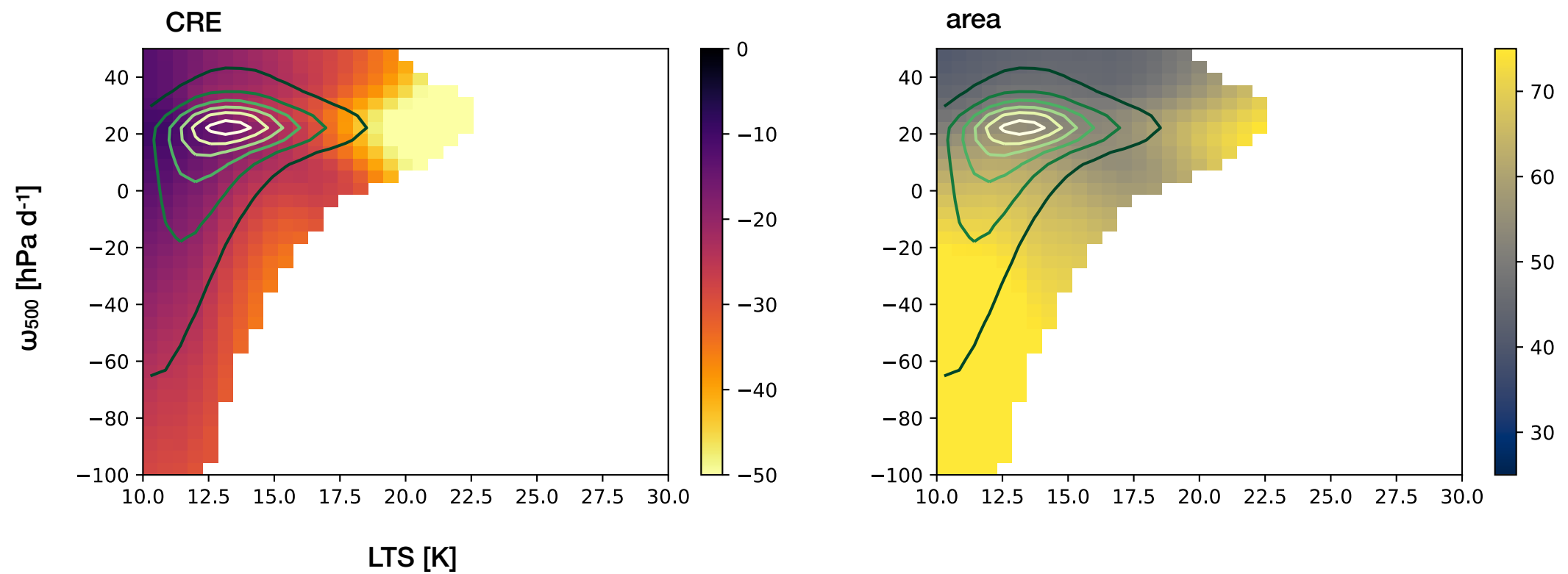
AVG: -3.58



## CERES EBAF & ERAI

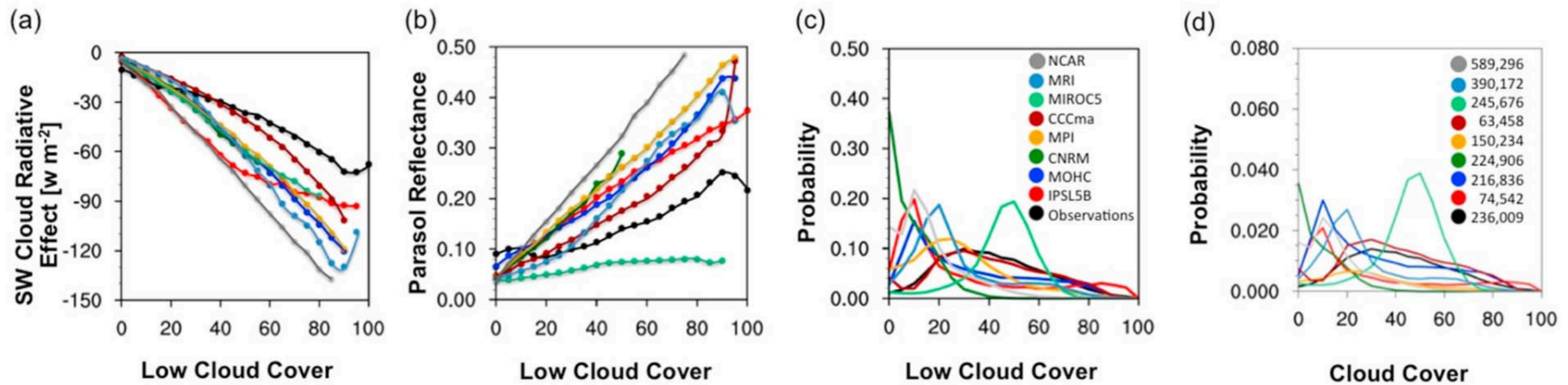


## CESM2

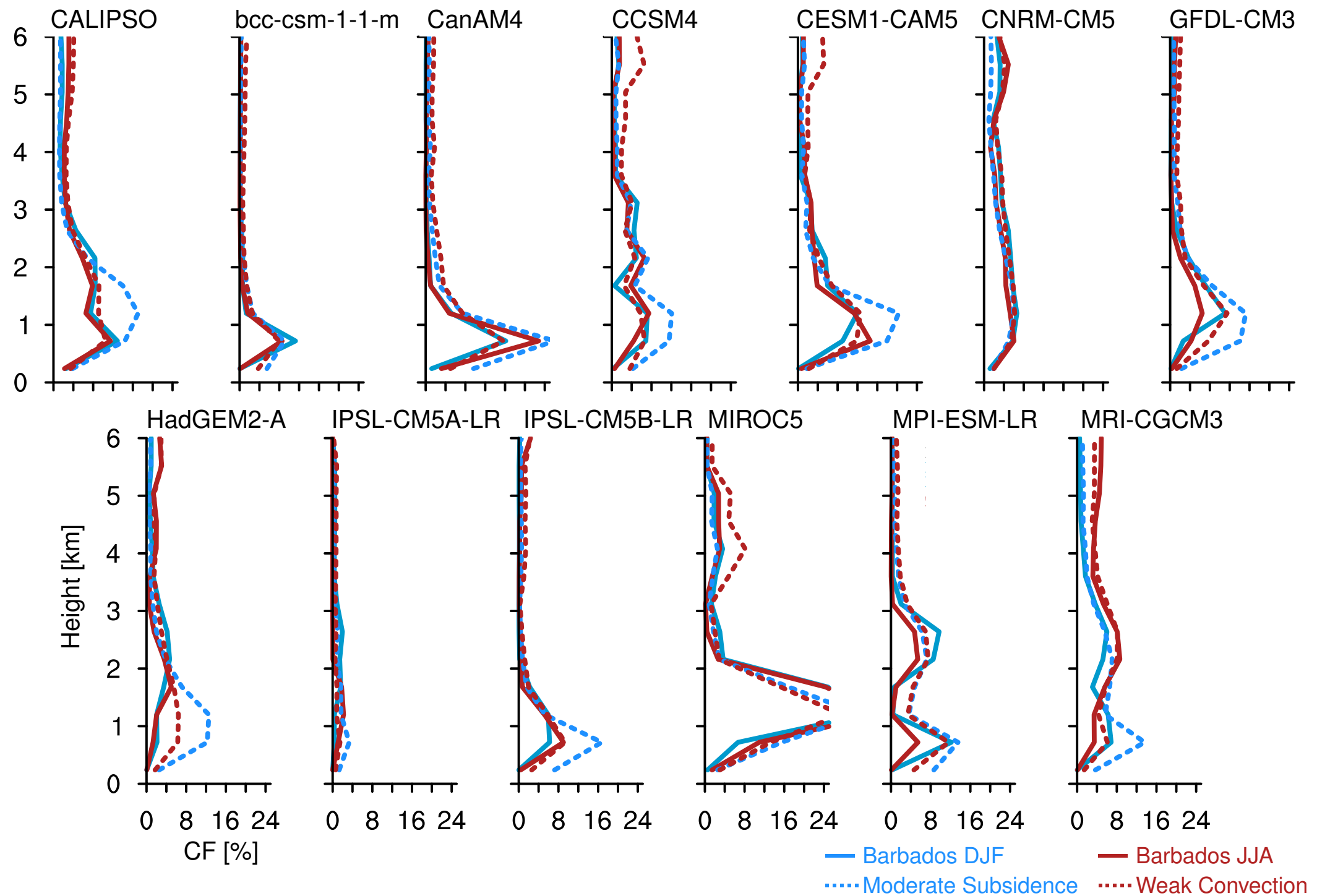




# Climate models have errors in BL clouds: “too few, too bright”



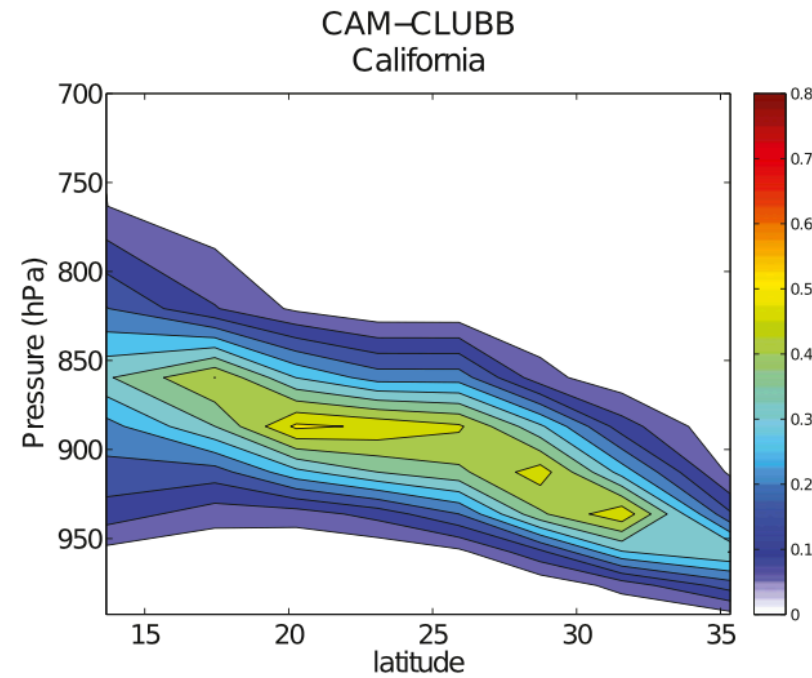
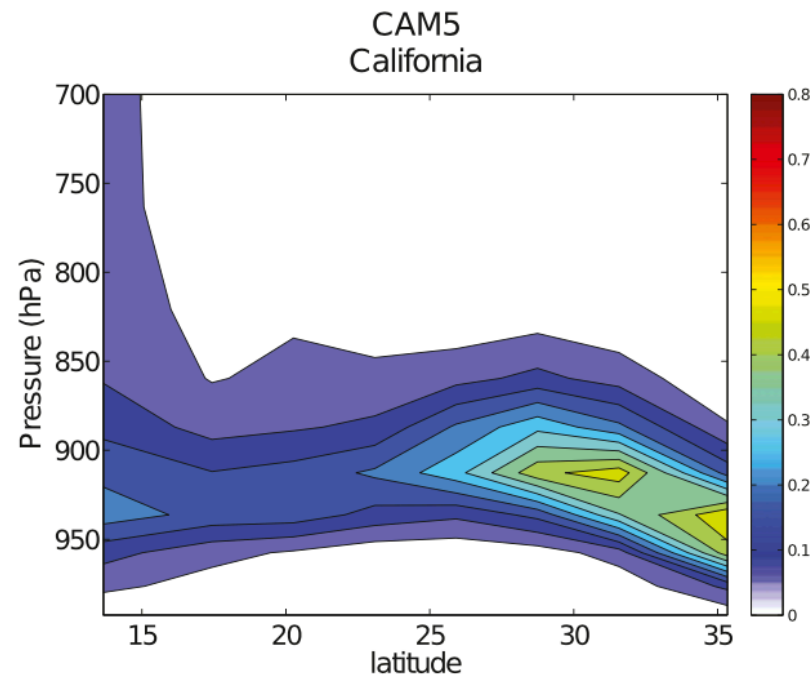
# Climate models' vertical structure



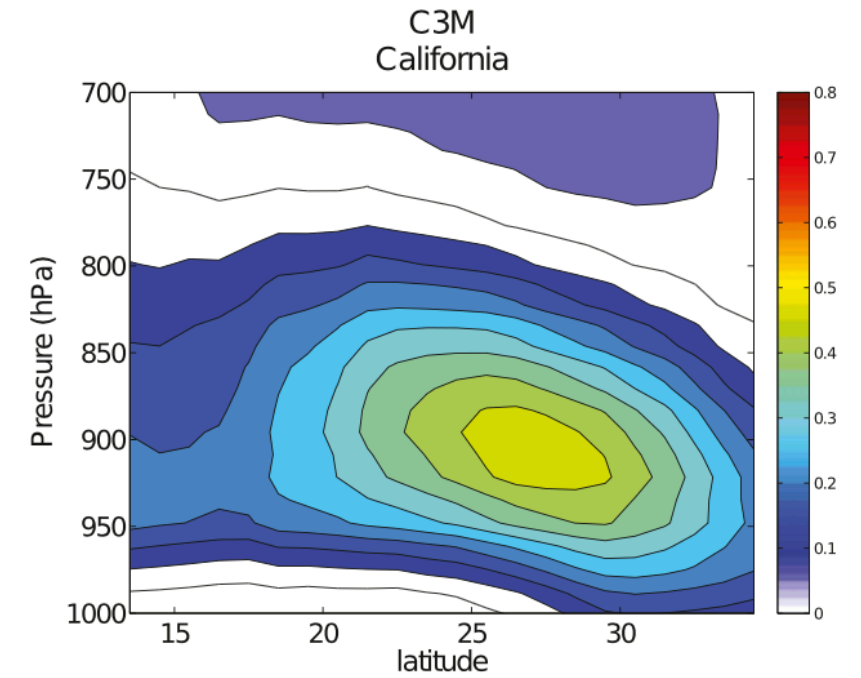


# Simulated Sc-to-Cu Transition

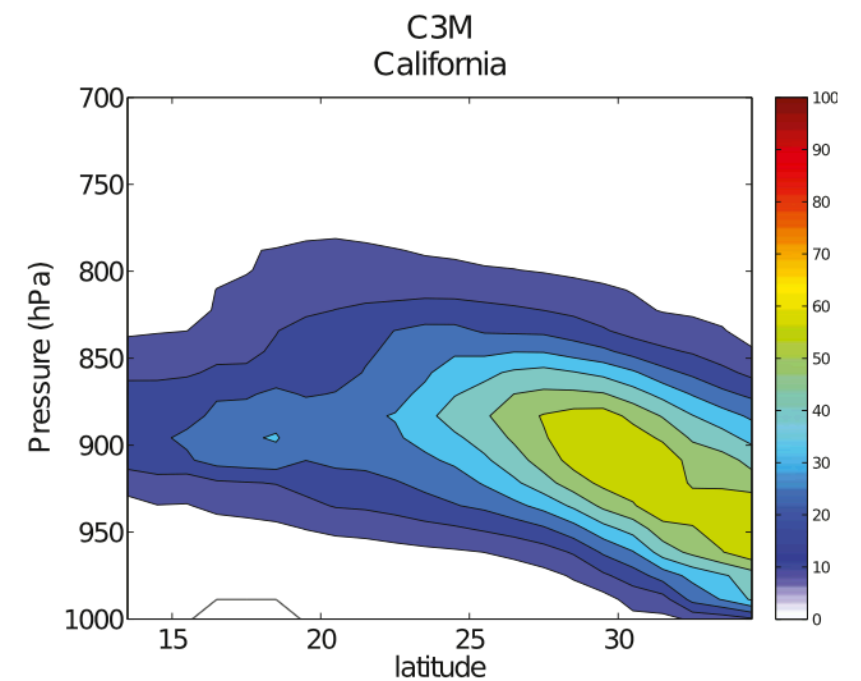
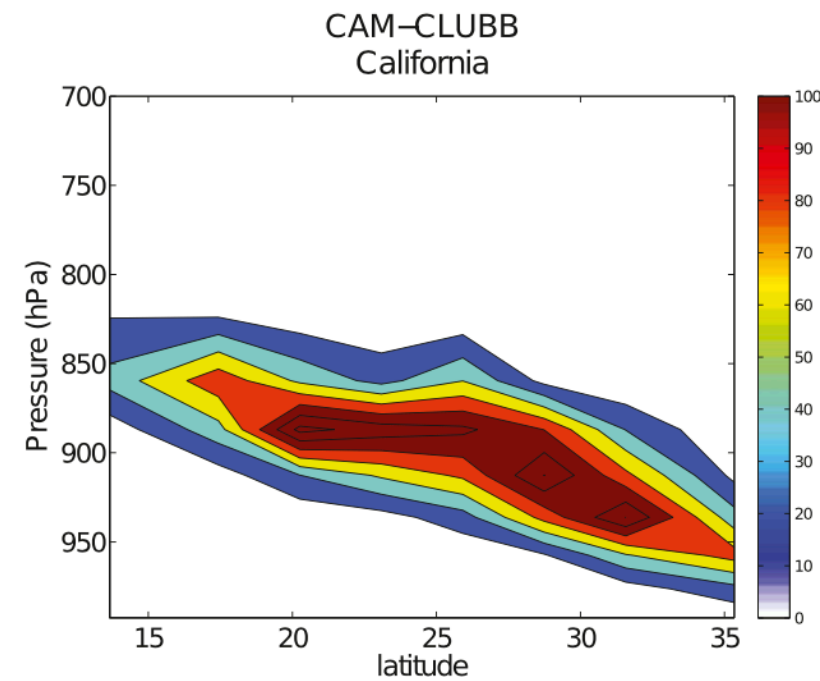
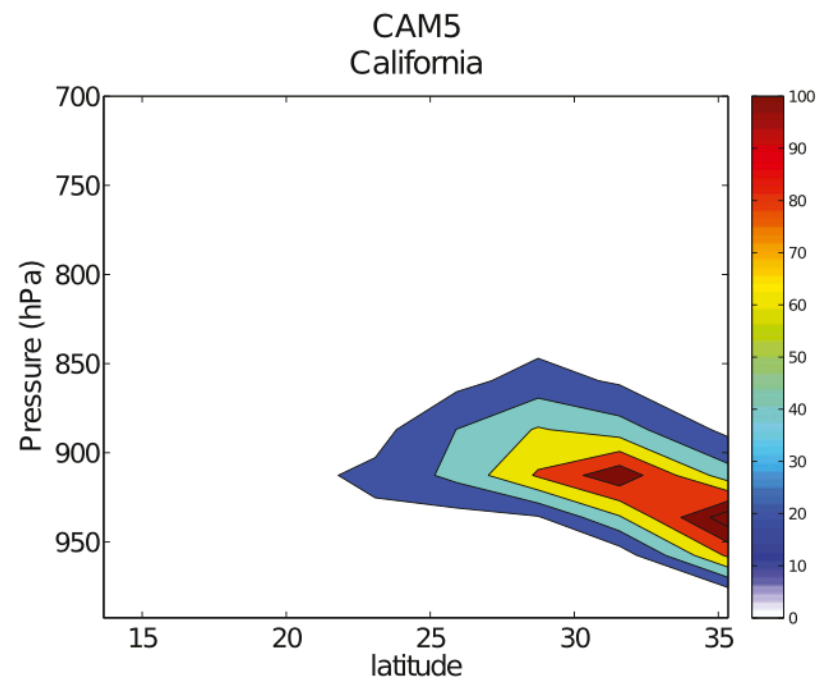
## Cloud Fraction



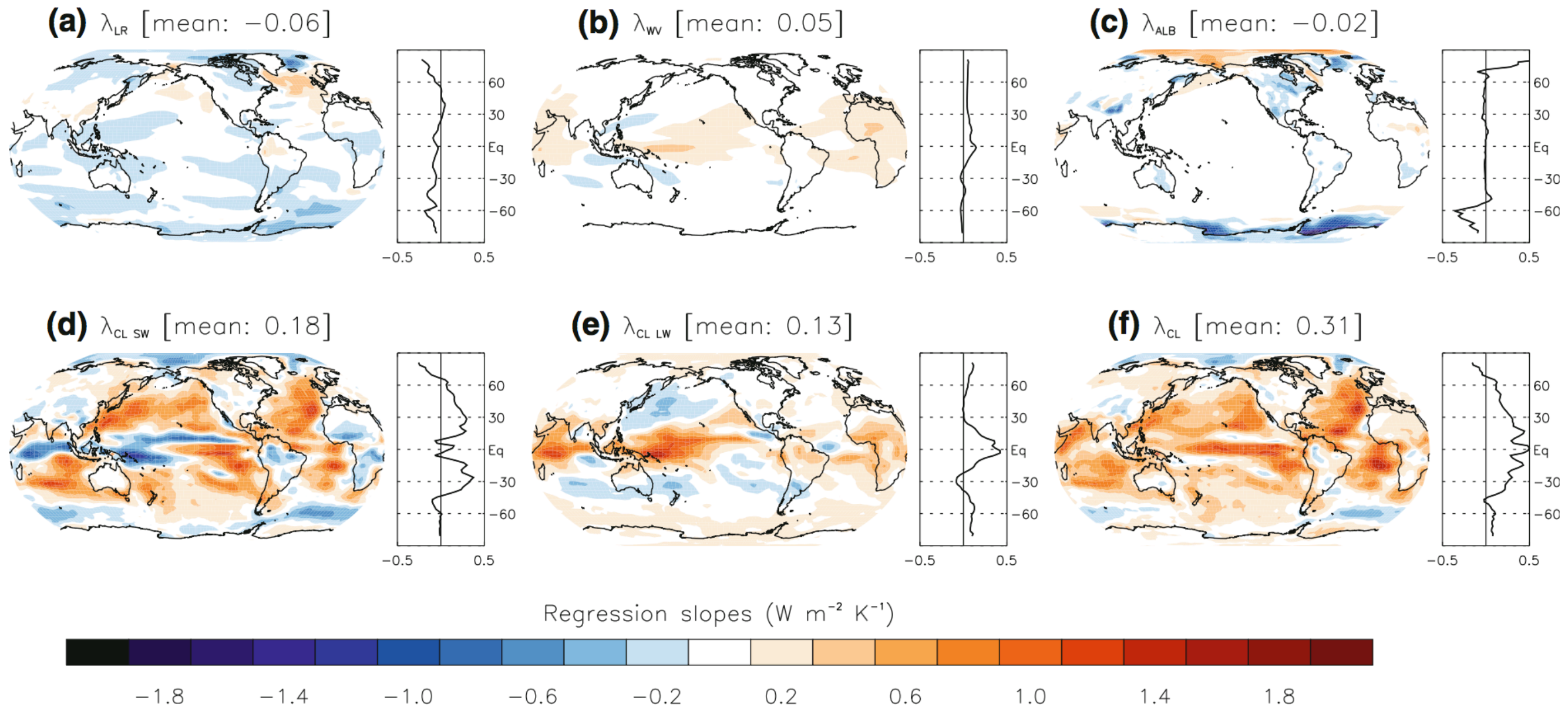
## Satellite-based product



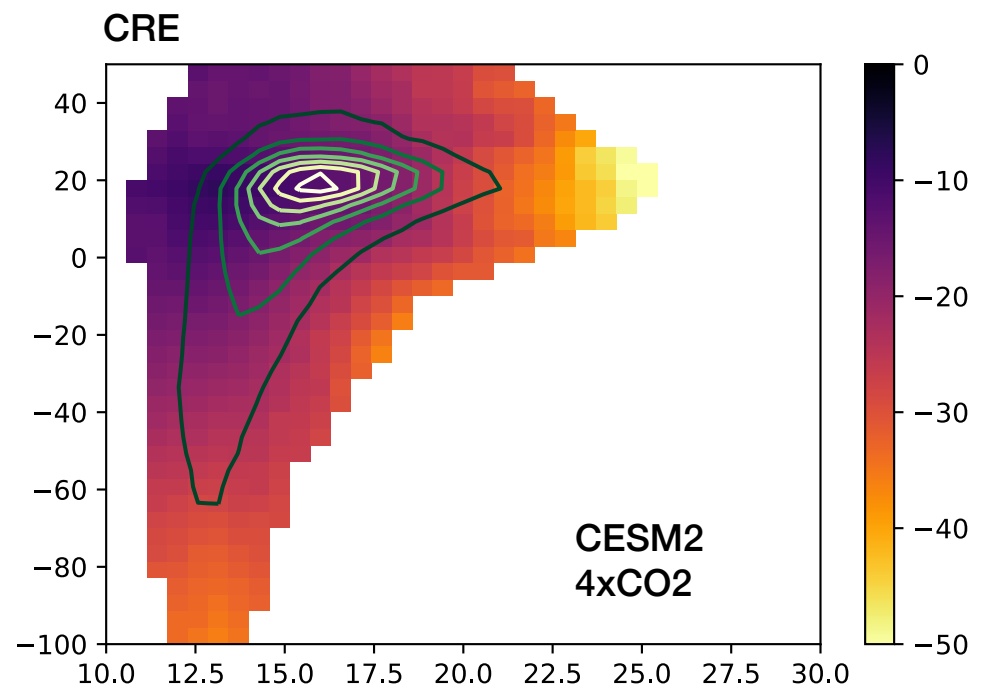
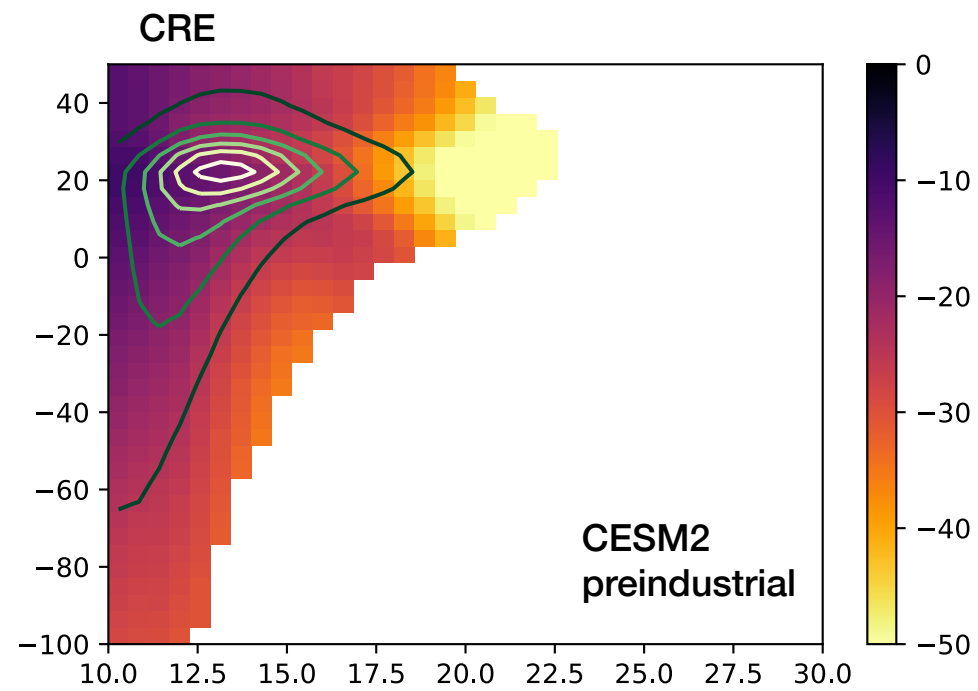
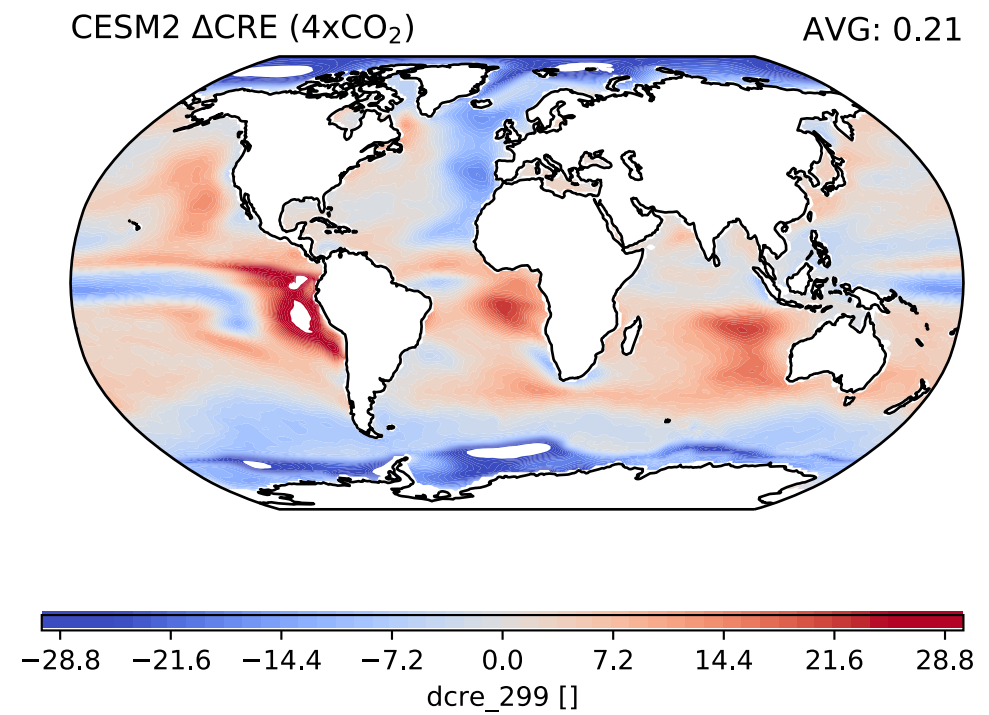
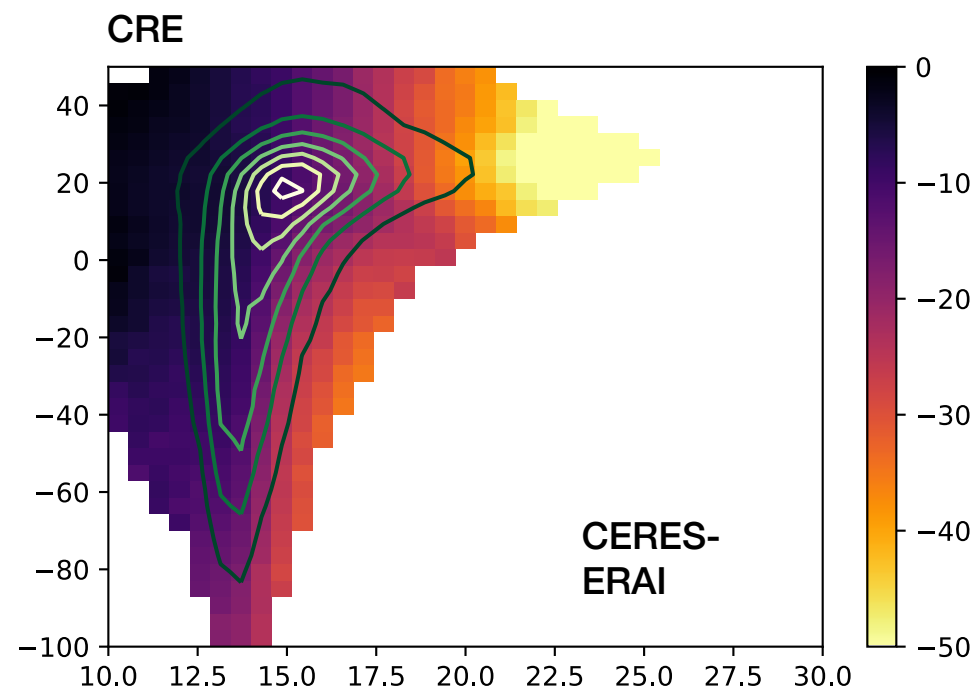
## Cloud Liquid



# Cloud feedbacks are very uncertain in climate models







# Closing

## Boundary layer clouds are a major contribution to Earth's energy balance

- They are low, mostly liquid, and highly reflective
- Tropical/subtropical stratocumulus and shallow cumulus are about 25% of the total TOA cloud effect
- broader trades cover MUCH more area, account for 2x more TOA cloud effect than stratocumulus decks

## Early evaluation of CESM2

- Broad spatial patterns of cloud cover are pretty well captured
- Still exhibits compensating errors between cloud cover and optical properties
- Biases in thermodynamic structure and circulation complicate evaluation

## Climate models more generally

- similar issues as CESM2: compensating errors, poor vertical structure
- At least partially responsible for uncertainty in cloud feedbacks